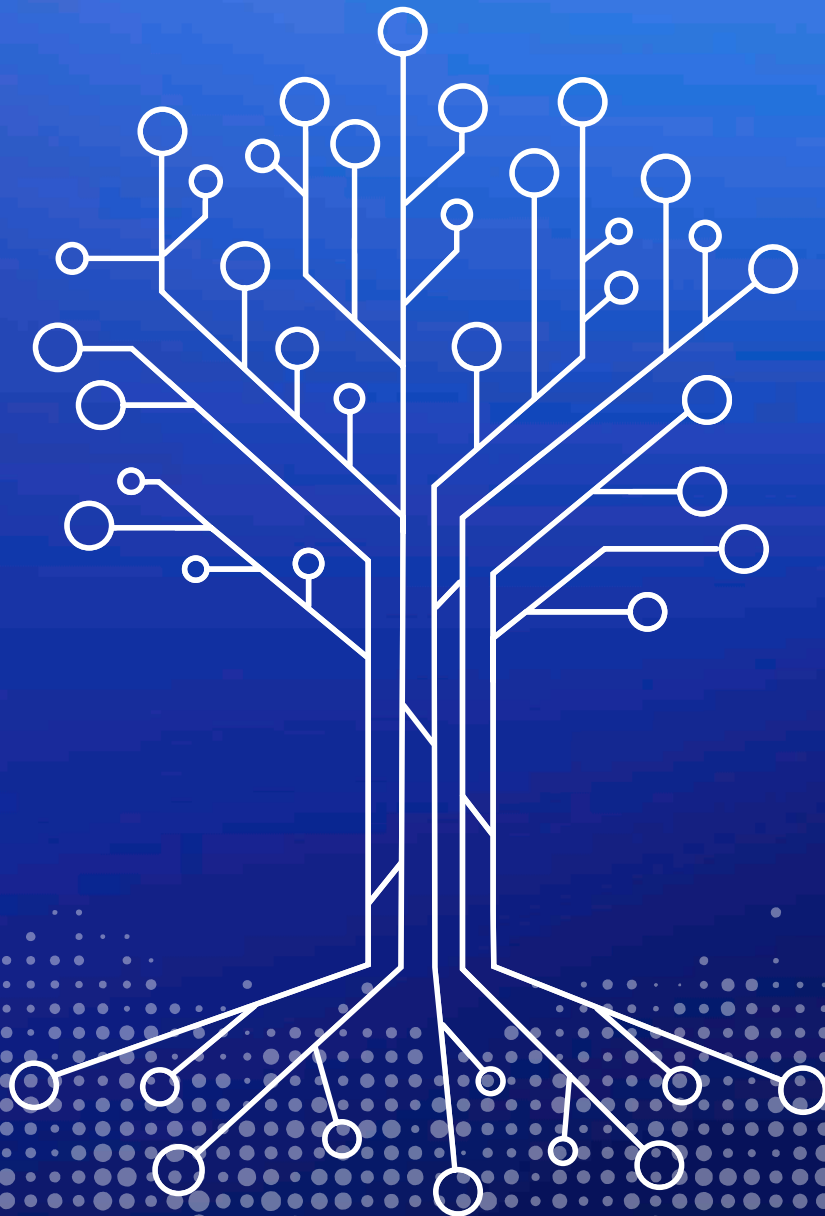


GAIA-X

GAIA-X: Driver of digital innovation in Europe

Featuring the next generation of data infrastructure



Imprint

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Disclaimer

This document is a high level view to describe the processes, components and mechanisms of GAIA-X for a broad audience. It summarizes current working results of the Workgroups and includes a proposal for technical architecture, substantial Policies and Federation Services.

This document serves as a base for further alignment and development with other European and international initiatives, partners and ruling decision-making bodies.

Introduction

Data and digital infrastructures play a key role in the economy. However, in order to exploit their full potential, obstacles that inhibit further development must be addressed. Currently, digital service users cannot make entirely self-determined decisions. This is caused by, for example, a lack of transparency over stored and processed data and the underlying infrastructure. There is also insufficient clarity about applicable jurisdictions and an insufficiently broad and inaccessible base of provider, service and technology choices. Sector-specific data spaces, the lack of an ontology and the absence of widely accessible application programming interfaces (APIs) further demonstrate that current activities are taking place in relative isolation. This obstructs innovation and the development of a supportive **framework for collaboration**.

The initiative GAIA-X addresses these obstacles. The goal is to set up a data and infrastructure ecosystem that is true to European values and standards. GAIA-X relies on data protection, openness and transparency, authenticity and trust, digital sovereignty and self-determination, free market access and value creation, modularity and interoperability as well as user-friendliness to build a federated ecosystem.¹ It will build on existing open standards to enable innovative services. Users and providers will have equal and non-discriminatory access to the GAIA-X ecosystem. It seeks to enable an accelerated and broad use of secure and trusted data services, with an emphasis “on the involvement of small to medium-sized enterprises in innovation-driving ecosystems.”^{1, 2}

GAIA-X’s mission is to **strengthen digital sovereignty** for business, science, government and society by empowering the development of innovation ecosystems. Digital sovereignty means that these individuals, organizations and communities stay in complete

control over stored and processed data and are enabled to decide independently who is permitted to have access to it. Furthermore, the initiative aims to

- reduce dependencies
- increase transparency and attractiveness of digital services
- and bring together digital infrastructures to foster innovation

In order to achieve digital sovereignty, GAIA-X focuses on the creation of guidelines, policies, and a technical target architecture, which includes **Federation Services** according to requirements for data and infrastructure ecosystems. GAIA-X also develops an **Architecture of Standards** and describes and aligns used standards and codes of conduct, enforces data usage policies, develops a federated catalogue of service with a uniform and provider agnostic interface, ensures identity and access management of GAIA-X entities, aims at enabling interoperability and interconnection as well as portability of infrastructure, applications and data across service providers, thus supporting the **free-flow of data**.³

As the impact of data-driven business models on European economy grows, GAIA-X will contribute to increasing the availability of digital services. It will create new opportunities for value and business innovation by providing common schemes and rules for collaboration within and across domains.

1 <https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/project-gaia-x.html>

2 https://www.bsi.bund.de/DE/Themen/DigitaleGesellschaft/CloudComputing/Grundlagen/Grundlagen_node.html

3 Digital Single Market: Commission publishes guidance on free flow of non-personal data (May, 2019) https://ec.europa.eu/commission/presscorner/detail/en/IP_19_2749

Digital Sovereignty

We understand digital sovereignty,¹ consistent with the definition of terms used by the Digital Summit Focus Group ‘digital sovereignty in a Connected Economy’, as the ‘possibility of independent self-determination by the state and by organisations’ with regard to the ‘use and structuring of digital systems themselves, the data produced and stored in them, and the processes depicted as a result.’ Our project primarily addresses the aspect of data sovereignty included in this definition of the term: i.e. ‘complete control over stored and processed data and also the independent decision on who is permitted to have access to it.’²

1 The German term “Digitale Souveränität”, which is used in the German original version of the concept paper, does not have a direct equivalent in the English language. Both “digital sovereignty” and “digital autonomy” are frequently used, with slight variations in meaning. When we use the term “digital sovereignty” in this translation, it has the meaning defined in more detail in this paragraph. The same applies mutatis mutandis to related translated terms, e.g. “Datensouveränität”/“data sovereignty”.

2 Definitions of terms from ‘Digital Sovereignty and Artificial Intelligence – Preconditions, Responsibilities and Recommendations for Action’, Focus Group ‘Digital Sovereignty in a Connected Economy’, 2018; ‘Digital Sovereignty in the Context of Platform-Based Ecosystems’, Focus Group ‘Digital Sovereignty in a Networked Economy’, 2019; and also from ‘Role Model 2030 for Industrie 4.0 - Structuring Digital Ecosystems Globally’, Plattform Industrie 4.0, 2019.

Executive Summary

Concept & Added Value

As the impact of data-driven applications on the European economy has grown over the years – and is likely to even accelerate due to the measures against COVID-19 pandemic – emerging digital ecosystems are faced with a variety of challenges that inhibit further development and collaboration. These challenges include:

- Decentralised processing locations
- Multiple technology stacks
- Lack of transparency and sovereignty over stored and processed data and infrastructure
- Insufficient clarity about the applicable jurisdiction
- Sector-specific data spaces and lack of ontology
- Absence of widely accessible application programming interfaces (APIs)
- Multiple stakeholders and difficult accessibility of existing data and infrastructure services

The project GAIA-X addresses these challenges through the establishment of data and infrastructure ecosystems according to European values and standards. Further more, it enables data sharing and a next generation of smart services. It will enhance the development of federated, trusted and a user-friendly digital ecosystem.

It will enable mechanisms for the sharing and processing of data across different parties in a sovereign and transparent way.

By defining applicable policy rules and architecture of standards for a federated ecosystem that relies on EU values and standards, it will also ensure that data-driven value creation remains with individual participants.

GAIA-X allows data to become more widely available, as it opens up high-value shared data spaces and datasets across the EU. It enables data sharing and a next generation of smart services.

GAIA-X fosters the creation, formation, roll-out and growth of digital ecosystems that can be commercially leveraged in and across data spaces. It drives value, business cases and innovation towards different target groups including consumers, providers and facilitators such as industry, the public sector or academia. GAIA-X adds significant value from data and infrastructure perspectives, as it:

- enables self-determined data-based business models from an entrepreneurial perspective;
- supports innovative collaborations across industries to aggregate and raise the value of data;
- promotes fair and transparent business models by providing the rules for such collaborative approaches, including the legally compliant use of data;
- provides common data monetisation schemes, sharing models and rules to enforce this. As such, the commercialisation of data becomes less complex and costly;
- enables collaboration across industries to create federated, interoperable services on the infrastructure layer;
- eases access to trustworthy next generation IT infrastructure (self-service, API-driven Infrastructure as Code), which will provide a productivity boost for software engineering teams; and
- supports the detection and preservation of data protection classes and confidentiality rules even in the case of “mixed” data allocations. Hence, the value leakage of enterprise data sets is prevented.

These value propositions are not exhaustive. We expect them to grow over time.

Target Architecture & Federation Services

Based on the perspective of different user groups and use cases, GAIA-X members have elaborated and continue to examine a set of service areas and requirements necessary for the technical operation of GAIA-X.

GAIA-X focuses on the creation of guidelines, policies, and a technical target architecture, which includes Federation Services according to requirements for data and infrastructure ecosystems. It is also developing an Architecture of Standards, describing and aligning standards and codes of conduct while enforcing data usage policies.

GAIA-X defines a set of policy rules and architecture of standards to support portability, interoperability and interconnection for infrastructure, applications and data. It provides the necessary link between different ecosystem participants to connect the following architecture levels:

1. Data Ecosystem

Based on elaborated use cases, GAIA-X fosters ontologies for interoperability and API within and across sector specific data spaces according to EU data strategy. This will promote the emergence of Advanced Smart Services comprising eg. Artificial Intelligence (AI), Internet of Things (IoT) or Big Data market places and applications within and across data spaces.

2. Infrastructure Ecosystem

Federated services provide value if they are based on common standards which ensure transparency and interoperability. GAIA-X addresses this requirement by aligning network and interconnection providers, Cloud Solution Providers (CSP), High Performance Computing (HPC) as well as sector specific clouds and edge systems. Here, mechanisms are developed to find, combine and connect services from participating providers in order to enable a user-friendly infrastructure ecosystem.

3. Federation Services

GAIA-X identifies the minimum technical requirements and services necessary to operate the federated GAIA-X Ecosystem. The development of these services will follow the principles of Security by Design and also include the concept of Privacy by Design in order to ensure highest security requirements and privacy protection.

Technical implementation of these Federation Services will focus on the following areas:

- the implementation of secure federated identity and trust mechanisms (security and privacy by design);
- sovereign data services which ensure the identity of source and receiver of data and which ensure the access and usage rights towards the data;
- easy access to the available providers, nodes and services. Data will be provided through federated catalogues;
- the integration of existing standards to ensure interoperability and portability across infrastructure, applications and data;
- the establishment of a compliance framework and Certification and Accreditation services; and
- the contribution of a modular compilation of open source software and standards to support providers in delivering a secure, federated and interoperable infrastructure.

The initial set of federation services will be expanded. The roadmap is aligned with the development of ecosystem participants' requirements.

Outlook

GAIA-X members have defined a roadmap for the technical implementation. The roadmap includes and contributes to the Federated Services of GAIA-X and an overall governance framework which is essential for the future setup of the project. The roadmap topics are organised in work packages in order to achieve first prototypes by early 2021. The initiative will be accompanied by facilitating research & development (R&D) programs where needed. In addition, the integration of European and international partners remains a major component of the initiative and will be further enhanced.

Part I GAIA-X Concept

GAIA-X started as a project to promote a federated data infrastructure as the cradle of a vibrant European ecosystem. It was launched by representatives of government, business and the science communities as a project initiative. It shares the objectives and targets of the current European strategy for data⁴ of the European Commission. It will jointly enhance the development of federated, trusted and user-friendly digital ecosystems based on fundamental European values:

- It will enable mechanisms for sharing and processing data across different parties in a sovereign and transparent way.
- It will ensure that data-driven value creation remains with the individual participants. This is achieved by defining applicable policy rules and architecture standards for federated ecosystems which respect EU values and standards.
- GAIA-X allows data to become more widely available by opening up **high value shared data spaces**. And publicly and privately held datasets across the EU. The initiative enables data sharing and new service design; e.g. to federated energy-efficient and trusted infrastructure and related services.

To empower a sovereign data ecosystem, the initiative will support the emergence of a vibrant ecosystem of open, interoperable, federated and secure infrastructure and service providers. It will also provide a standardised, modular open source implementation for an infrastructure software stack. Moreover GAIA-X intends to increase the transparency of the **digital infrastructures' sustainability**.

Based on the perspective of different user groups and use cases, project partners have elaborated on and continue to examine a set of service areas and requirements which are necessary for the technical operation of GAIA-X.

Goals and added Value of GAIA-X Ecosystem

GAIA-X paves the way for a resilient, reliable and flexible digital infrastructure based on European values⁵. The initiative will create benefits for organisations and provide a new level of trust for collaboration within and across data spaces.

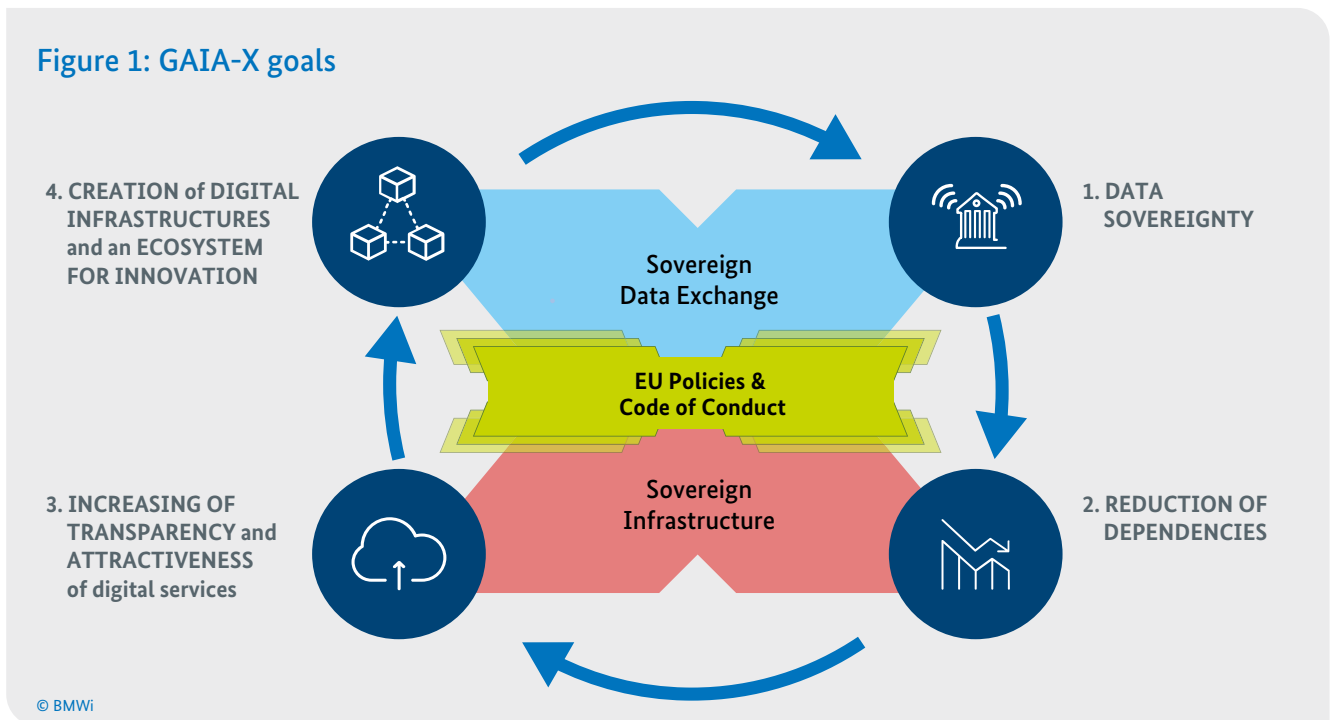
GAIA-X establishes a trusted environment between partners and interoperable links between smart service applications and infrastructure services, thus creating a user-friendly, accessible and transparent digital ecosystem for innovations. Thus GAIA-X enables a free, though secure and auditable, flow of data in accordance with the existing regulations of the EU and its member states and based on accreditation and policy enforcement.

Data sovereignty and freedom of choice is a major goal of GAIA-X. Data providers execute self-determined control over stored and processed data. Data consumers rely on data from trustworthy sources. Depending on individual and sector-specific requirements, users can choose from services meeting their demands relating to e.g. rigorous information-security requirements, legal certainty within the framework of the European General Data Protection Regulation (GDPR), data storage within certain countries or regions or other specific attributes that users can leverage in making their choice. The proposed Federation Services of GAIA-X thus focus on the establishment of interoperability on certain aspects such as data semantics, on the creation of trust among different parties based on certified degrees of protection as well as accepted and enforceable governance (see Part II).

4 https://ec.europa.eu/info/sites/info/files/communication-european-strategy-data-19feb2020_en.pdf

5 BMWi Project GAIA-X, October 2019 <https://www.bmwi.de/Redaktion/EN/Publikationen/Digitale-Welt/project-gaia-x.html>

Figure 1: GAIA-X goals



GAIA-X aims to **reduce dependencies** on different levels. First, the increased range of accessible services will reduce dependencies for private and business consumers from single providers. Secondly, GAIA-X will facilitate the promotion of European values by applying EU and member state regulation. This will open up new opportunities for European lawmakers to set new standards and promote good and sustainable practices.⁶ Moreover, it will allow GAIA-X participants to maintain control of the location and regulatory environment where their data is stored. Finally, GAIA-X will reduce sector-specific dependencies on certain technologies and digital applications. As a standard of standards, GAIA-X will build the common ground for connecting sector-specific applications. This will improve capabilities for collaboration and join forces on a cross-sector basis.

Finally, GAIA-X will give a broad audience access to smart and high performance data processing services. On the one hand, it aims to increase transparency in different infrastructure and data services. On the

other hand, it will reduce the barriers to compliant usage of these services, making it **more attractive for customer groups** like small and medium-sized enterprises (SME) or public administrations. Higher market adoption will increase internal scale, thus strengthen market competition.

GAIA-X aims at enabling a user-friendly, secure and high-performing environment for all crucial systems, critical sectors and industries in the strategic interest of the European Union and its member states.

Moreover, GAIA-X creates new opportunities for cross-sector collaboration and innovation by simplifying the exchange of sector-specific data. Finally, it empowers users to stay in control of their data and enhances the digital skills of SMEs.

Added value

GAIA-X fosters the creation, formation, roll-out and growth of digital ecosystems that can be commer-

6 Franco-German Position on GAIA-X <https://www.bmwi.de/Redaktion/DE/Downloads/F/franco-german-position-on-gaia-x.html>

cially leveraged in and across domains. It drives value, business cases and innovation towards different target groups including consumers, providers and facilitators like the public sector or academia.

The GAIA-X data and infrastructure ecosystem offers added value for intra and inter domain exchange of data and services beyond provider and consumer boundaries.

GAIA-X target groups

Consumers

- Individuals/end consumers

While GAIA-X: primarily targets a business-to-business model and focuses on business consumers in the first place, GAIA-X's leading principles place the individual citizen at the center of all its considerations.

- Business consumers

From a business consumer perspective, a wide variety of sectors and domains can benefit from GAIA-X while there are certain sectors such as healthcare, public sector, finance or critical infrastructures where a sovereign data infrastructure is essential. However, all sectors can and should participate in the GAIA-X project.

- Consumer and Industry Associations

There are multiple consumer and industry associations that represent different interests and sectors. They will be an integral channel for GAIA-X and its consumers to further align demand, requirements and strategic directions.

Providers

- Software Infrastructure Providers

Software providers for Infrastructure-as-a-Service or low-level Platform-as-a-Service are essential to build the core architecture of GAIA-X's harmonisation and orchestration efforts, small and mid-sized companies in particular.

- Platform and Service Providers

Platform and Service Providers build their solutions on top of the core infrastructure services and in turn offer further services to the end consumers.

- Providers of Physical Infrastructure

The mentioned services rely on a physical infrastructure like data centers, the respective hardware as well as the interconnection/networking. Providers of physical infrastructure offer essential building blocks and services within the GAIA-X ecosystem.

- Provider Associations

Same as the associations on consumer side, provider-side associations help to streamline communication among providers but also with consumers, politics, regulatory bodies and others.

Facilitators

- Politics

Representatives from politics and governments are to be involved as GAIA-X addresses also political concerns like security and industrial policy aspects.

- Research

GAIA-X builds on a variety of established concepts and technologies but also requires further research and development.

Value added from data and infrastructure perspective:

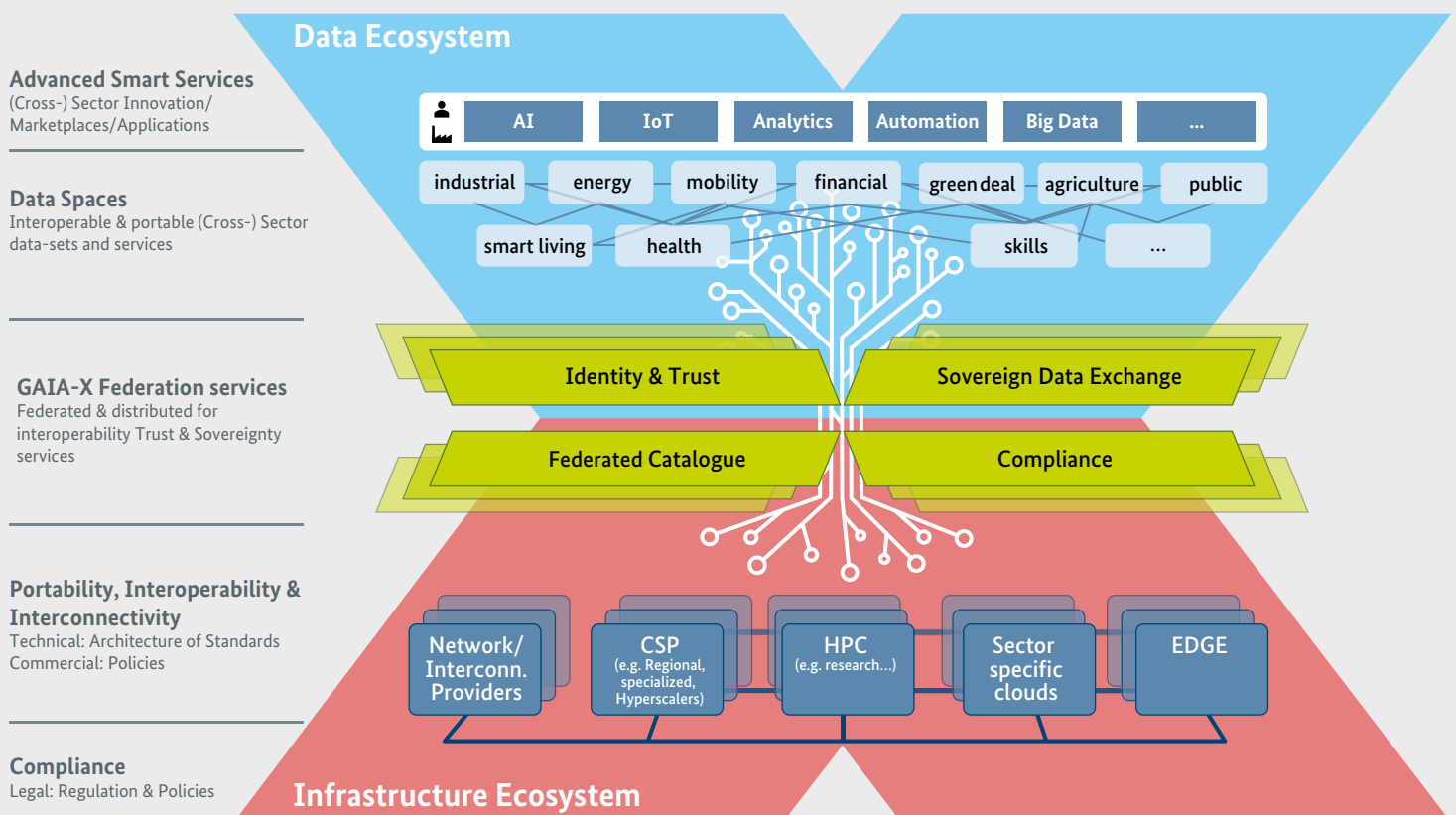
- Enable self-determined data-based business models from an entrepreneurial perspective
 - Enable innovative collaborations across industries to aggregate data and raise the value of data
 - By providing rules of the game for collaborative approaches, including legally compliant use of data, fair and transparent business models are enabled
 - By providing common data monetisation schemes, sharing models and rules to enforce this, the commercialisation of data becomes less complex and costly
 - Enable collaboration across industries to create federated and interoperable services on the infrastructure layer
- Easy access to trustworthy modern IT infrastructure (self-service, API-driven Infrastructure as Code) will provide a productivity boost for software engineering teams
 - Supporting the detection and preservation of data protection classes and confidentiality rules, even in the case of “mixed” data allocations prevents the value leakage of enterprise data

These value propositions are not exhaustive. We expect them to grow over time.

GAIA-X Target Architecture

GAIA-X defines a set of policy rules and architecture of standards to support portability, interoperability and interconnection for infrastructure, applications

Figure 2: GAIA-X Architecture overview



and data. It provides the necessary link between different ecosystem participants to connect the different architecture levels. These levels comprise:

1. Data Ecosystems

Based on elaborated use cases, GAIA-X fosters ontologies for interoperability and API within and across sector specific data spaces according to EU data strategy. This will promote the emergence of Advanced Smart Services comprising e.g. Artificial Intelligence (AI), Internet of Things (IoT) or Big Data market places and applications within and across sectors.

2. Infrastructure Ecosystem

Federated services provide value if they are based on common standards which ensure transparency and interoperability. GAIA-X addresses this requirement by aligning network and interconnection providers, Cloud Solution Providers (CSP), High Performance Computing (HPC) as well as sector specific clouds and edge systems. Here, mechanisms are developed to find, combine and connect services from participating providers in order to enable a user-friendly infrastructure ecosystem.

3. Federation Services

GAIA-X identifies the minimum technical requirements and services necessary to operate the federated GAIA-X Ecosystem. The development of these services will follow the principles of Security by Design and also include the concept of Privacy by Design in order to ensure the highest security requirements and privacy protection.

In an initial approach, four areas of Federation Services were identified for the technical feasibility of the project.

In order to connect the various participants of both the data and the infrastructure ecosystem, GAIA-X defines a set of Federation Services:

- Federated Identity & Trust Services
- Federated Catalogues for Providers, Nodes and Services
- Sovereign data exchange which ensures that data is only distributed to the intended recipients and that data transmission, storage, usage and replication are controlled
- Compliance with the applicable legal regulation and policies

The initial set of federation services will be expanded, the roadmap is regularly adapted in line with the evolution of the requirements of the ecosystem participants.

GAIA-X Data Ecosystem – Innovation & Smart Service Business Models

The knowledge gained from data helps to improve business and social decisions. The accessibility of data becomes increasingly important – for private individuals, public institutions, start-ups, SMEs and corporations.

With its federated approach, GAIA-X creates a broad base for the access and exchange of data connecting citizens, organisations and resources in an interactive ecosystem. It ensures that the legal framework and operating standards for **data spaces** comply with EU data strategy.

In this respect, it allows the emergence of **Advanced Smart Services** like Big Data applications and market places to support innovation within and across sectors. It promotes the opportunity to collaborate in data-driven horizontal and vertical value chains. Moreover, it reduces the fragmentation of the internal market by giving SMEs and start-ups the same opportunities to make the most of big data to grow in the digital world. As a result, it fosters the emergence of sustainable business and innovation ecosystems for the next generation of digital infrastructure.

- Federated Identity & Trust Services

Sustainable business and innovation ecosystems

Sustainable ecosystems are defined by a number of agreements, mechanisms and rules which allow consumers and providers to exchange assets knowing that there is a fair and level playing field, that the ownership of the assets is clearly defined and that assets can be traded. If the availability of data and mechanisms to control and protect the usage of data is combined with new services and business models can be created (“innovation and competitive ecosystems”).

In order to enable data ecosystems, GAIA-X will provide the same mechanisms that we know from the physical world in the digital world. Thereby, GAIA-X enables both collaborative as well as innovation-driven and competitive ecosystems that allow each party to participate in an open ecosystem. In this

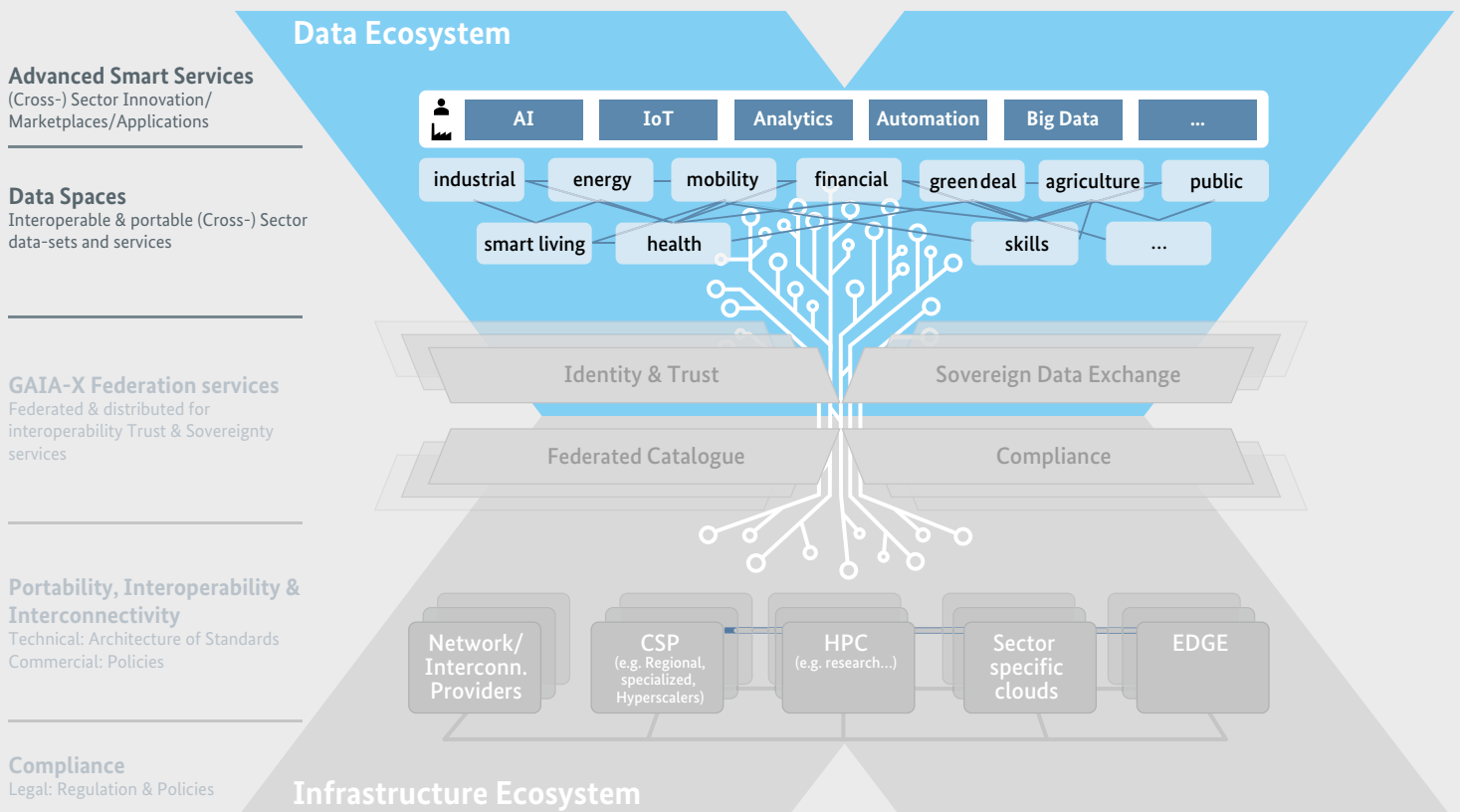
open ecosystem, all participants will work on a level playing field providing multiple enabling services that can be built on underlying enabling services with adequate assurance of regulatory compliance.

Along with the establishment of an ontology that helps to exchange physical goods, the data ecosystem will also provide interoperability for the underlying services, whether compute services, data management services or analytical services. This interoperability will be defined in the GAIA-X Architecture of Standards to ensure that the interaction with ecosystems outside of GAIA-X also works seamlessly.

Creating a framework for Collaboration

Industry companies are in the middle of a far-reaching transformation processes in value creation: The

Figure 3: Data Ecosystem



generation of vast amounts of operational data from millions of machines, systems and manufactured products changes value propositions. While current business models are at risk, new data-driven business models arise. In order to develop, new self-determined business models engage in new forms of collaboration.

However, this new form of collaboration faces restrictions. The scalability of digital services is limited by ongoing endeavours to implement mutual data storage and usage capabilities. Insufficient mechanisms for secure and trusted access to data increase the fear of the loss of data sovereignty and are obstructing deepened collaboration. Moreover, the lack of interoperability of services prevents market participants from sharing data in an automated and flexible way.

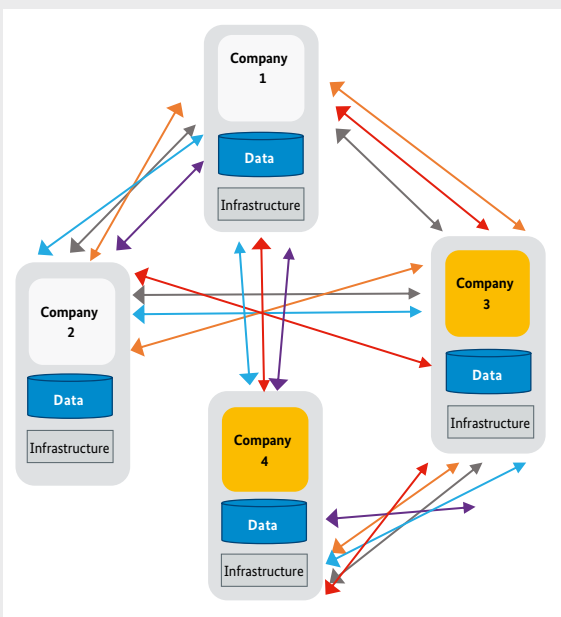
This is exactly what GAIA-X addresses. GAIA-X enables mechanisms to share and process data across different parties. This enables companies of various industries and of all sizes to manage their data assets confidently. This is not limited by geographical boundaries, but is driven by European values. Virtual data spaces support the secure exchange of data and facilitate the exchange of data in business ecosystems based on standards and common governance models, while maintaining data sovereignty. The data ecosystem preserves the digital sovereignty of the owner of the data and at the same time forms the basis for smart services and innovative business processes.

As a result, added value in several ways is generated: in horizontal value chains, it helps to effectively link supply- and demand side users, thus fostering the

Figure 4: Collaboration Today (left) and in GAIA-X Ecosystem (right)

Collaboration today

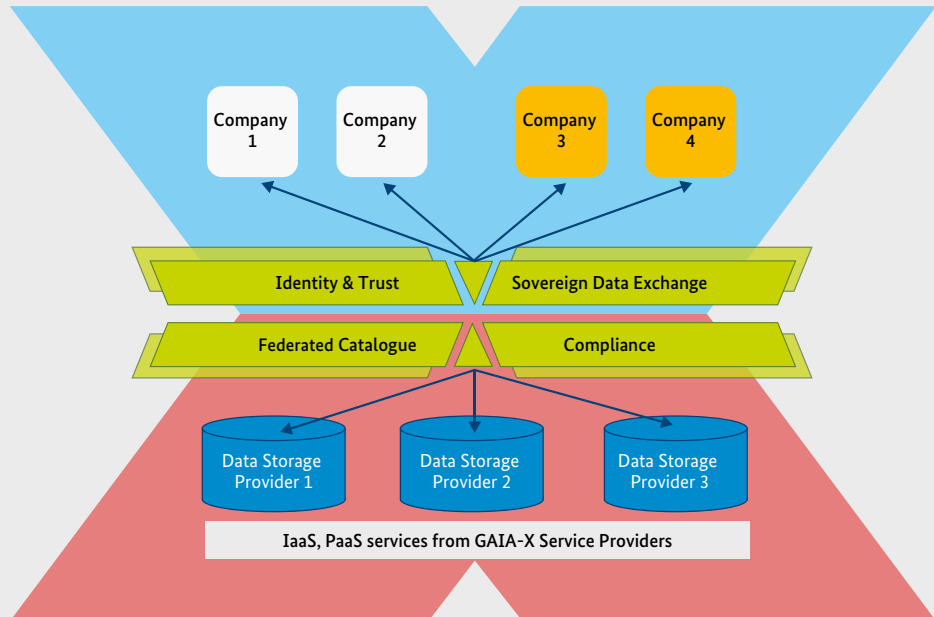
Today: Creation of multi-party services and data spaces requires high level of individual adaptations and agreements



- ◄ Visibility of services
- ◄ Identity
- ◄ Data Usage Controls
- ◄ Data Portability
- ◄ Interoperability

GAIA-X Eco-System

GAIA-X: Federation services and common Policy Rules and Architecture of Standards accelerate the creation of advanced smart services



Common Policy Rules, Architecture of Standards and GAIA-X Federation Services

ability to respond to the individual consumer's requirements. From a vertical perspective, it allows more suppliers to contribute to even more complex products and services, which ultimately enables specialised technology providers to effectively supply business functions.

GAIA-X Federation Services for the Federation of Ecosystems

Data is the raw material for innovation and the creation of smart business application and services. Data value chains are the prerequisite for innovation in business ecosystems. They arise from the acquisition of the data in sensors, devices, products etc. in Advanced Smart Services and include their preprocessing, storage and transfer to analysis. However, emerging digital ecosystems still face challenges, such as:

- Decentralised processing locations
- Multiple technology stacks
- Special policy requirements or regulated markets
- Secure access to respective data of multiple actors and stakeholders without losing sovereignty

GAIA-X addresses these challenges. It provides market participants, non-profit organisations, academia and public administrations with a flexible and user-friendly access to vast innovation ecosystems. **GAIA-X Federation Services** establishes a trusted connection between prevailing and emerging data and infrastructure ecosystems. It allows (or prevents) data from being analysed or linked. Third parties can be prohibited or allowed access to data according to transparently communicated policies and architecture of standards. Data sovereignty can also be guaranteed with respect to party digital infrastructure (e.g. interconnection, cloud or software).

The aggregation of data from different service providers is supported by GAIA-X Federation Services for Identity and Access and enables service providers and

consumers to share their data with agreed third parties and in accordance with data usage policy rules. These **data spaces**, with the access controls delivered by GAIA-X Federation Services, provide the basis for the new data-driven ecosystems, supporting innovation in research, business and creating new offerings and collaborative work models.

This is achieved by mutual agreements on applied standards based on existing standards and frameworks (Architecture of Standards). At its core, a federation of service consumers and providers across sectors and digital infrastructures builds the foundation for a trusted and joint action. The agreement consists of a set of defined policy rules and architectural standards which are applied to all participants in the GAIA-X Ecosystem. Therefore, the technical implementation will focus on the following:

- the implementation of secure federated identity and trust mechanisms (security and privacy by design);
- sovereign data services, which check the identity of source and receiver of data and which ensure data access and usage rights;
- easy access to the available providers, nodes and services. Data will be provided through federated catalogues;
- the integration of existing standards to ensure interoperability and portability across infrastructure, applications and data;
- the establishment of a compliance framework and Certification and Accreditation services,
- the contribution of a modular compilation of open source software and standards to support providers to deliver a secure, federated and interoperable infrastructure;
- the identification and development of further key Federation Services in the course of the project.

For a detailed description of the Federation Services please see Part II.

GAIA-X Infrastructure Ecosystem – Technical Foundations

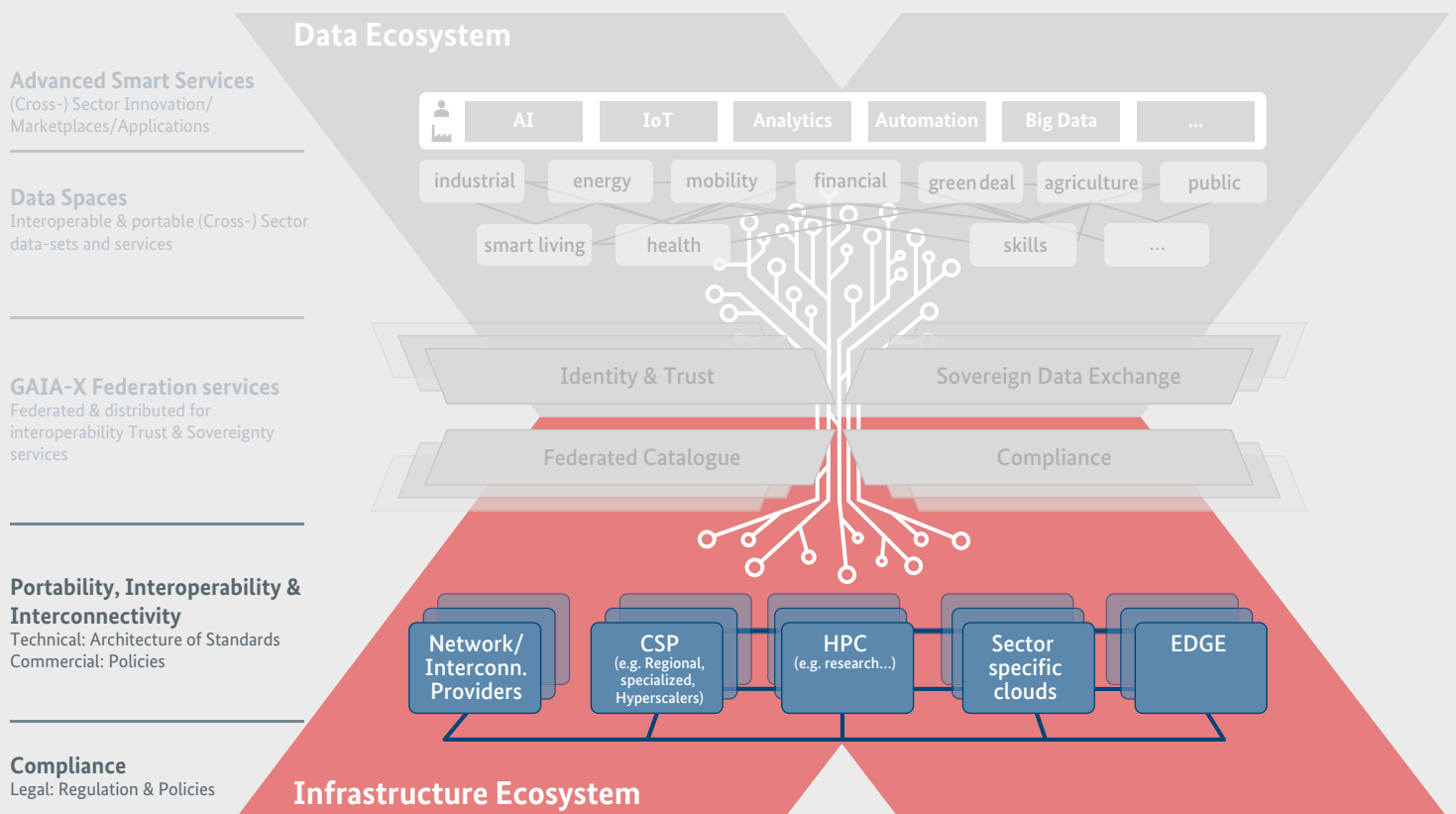
On a technical level, GAIA-X enables the management and usage of trusted, secure and federated infrastructure that are needed to enable sovereignty and self-determined processing and storing of data. It will serve as basis for the development of data and service ecosystems which allow for the seamless interaction of services and data and nurture innovative digitalisation use cases at a business level.

The technical level will serve as the foundation for fostering the digital ecosystem with consumers and providers as described in the previous chapter. Its main function is to provide **accessible and easily useable services and infrastructure** and to explicitly

allow small and medium-sized businesses to innovate jointly with European industry players – either through trusted collaboration or innovation.

GAIA-X creates an infrastructure ecosystem by establishing portability and interoperability between network and interconnection providers, Cloud Solution Providers (CSP), High Performance Computing (HPC), Sector specific clouds and edge systems. As a federated data infrastructure, GAIA-X supports distributed use cases, spanning from on-premise set-ups, cloud hosted infrastructure through to facility to edge cases. Thus, GAIA-X has to address the complete technical stack, including infrastructure and existing network/interconnection requirements (Architecture of Standards) of distributed use cases, e.g., latency and privacy requirements of the interconnecting network.

Figure 5: Infrastructure Ecosystem



In order to enable multi-cloud and edge use cases, interconnection providers are enabled by GAIA-X to provide new services. This allows the participants to have a **well-defined, transparent and auditable communication**, fostering use cases spanning services across governance and high-performance interconnects as well as the public internet.

Thus, the technical level enables a controlled way – dependent on use cases and policies – to provide and to use services and infrastructure offered by onboarded cloud service and network/interconnection providers. It addresses, furthermore, the need for a secure and trusted communication channel providing performance guarantees to maintain domain knowledge, improve competition between service providers and guarantee Europe’s digital sovereignty.

Towards a sustainable digital infrastructure

GAIA-X intends to increase the transparency of the digital infrastructure’s energy-efficiency, renewable energy sourcing and ecological sustainability. Service providers can add self-descriptions regarding sustainability-related technologies, policies, certificates, labels and key performance indicators for their infrastructure. Users will receive information on these sustainability aspects of the underlying infrastructure and thus will be able to make better informed decisions regarding their action’s impact on sustainability.

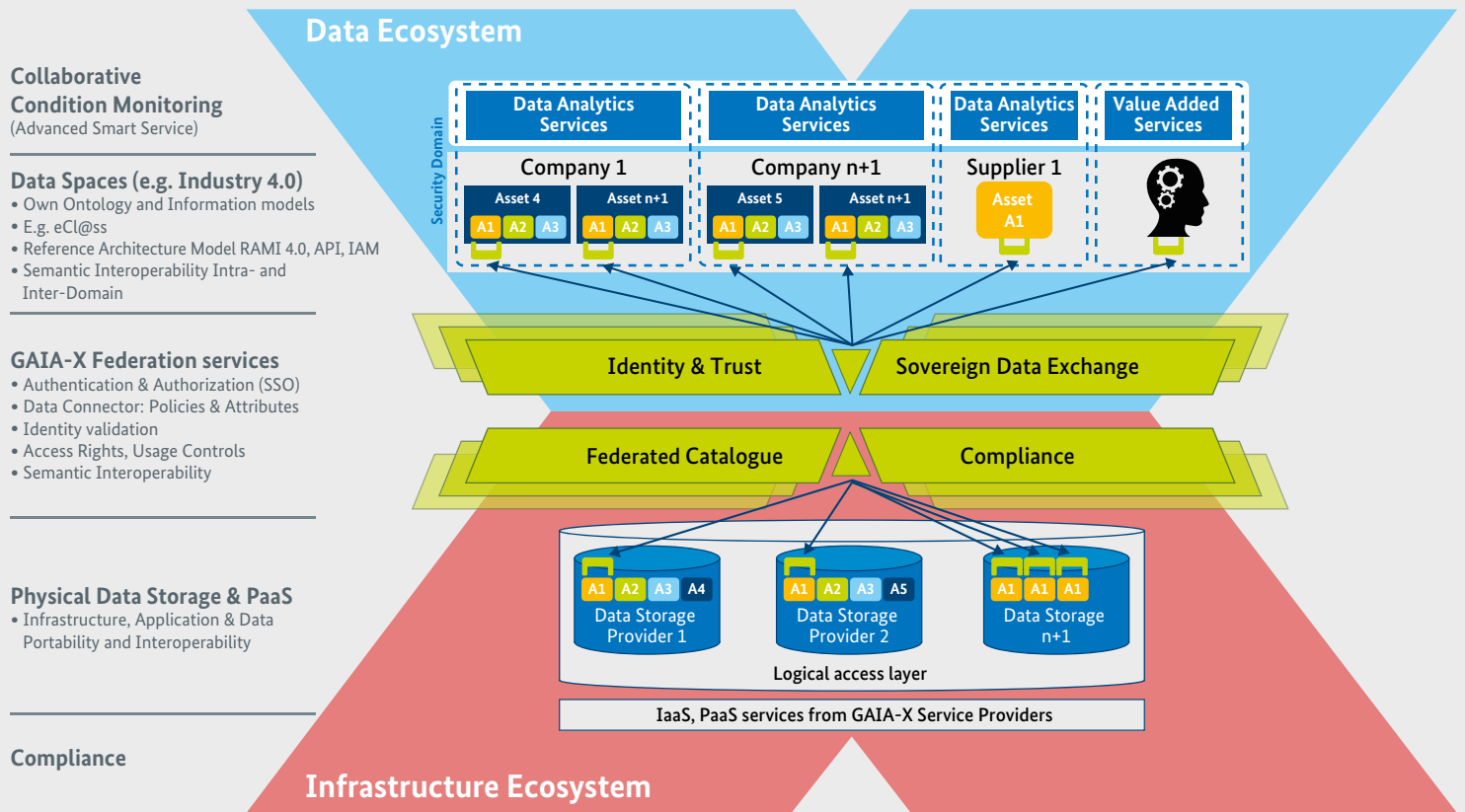
Use Case Collaborative Condition Monitoring (CCM)

In manufacturing, data is rarely used to develop data-based business models. However, it is a valuable resource that can form the basis of new data-based business models, e.g. data from the production process as well as operating data from millions of machines, systems and products. In order to harness this wealth of data and to be able to offer self-determined, data-based business models from an entrepreneurial perspective, innovative collaborations across company and competitive boundaries are necessary. Nowadays, data exchange between different supply chain partners is primarily driven by Original Equipment Manufacturers (OEM). This exchange usually happens only between two partners and primarily aims at optimising the production system of the OEM.

The GAIA-X use case Collaborative Condition Monitoring (CCM) demonstrates how a framework for collaboration can contribute to develop self-determined business models for the condition monitoring of production processes. It describes an innovative approach, according to which a wide variety of actors in the network (in this example: companies and suppliers) can create added value for everyone involved in the value chain by new business models. According to this, a common profit can be realised in the ecosystem if all actors share their data and make them available on an independent digital platform.

The added value generated from the collaboration can result e.g. in an increased life cycle of machines (compare figure: asset 4 and 5) or components (assets A1, A2 and A3). Artificial Intelligence applied to the data from different companies operating the machines will help the original supplier to understand better the operating conditions based on a diverse user base. For such data exchange a common semantic and methods for access control are needed. As the original data can be used to achieve competitive information, it is important to provide fine level access and usage controls to the data.

Figure 6: Use Case Collaborative Condition Monitoring in GAIA-X Infrastructure



Part II GAIA-X Federation Services

GAIA-X is designed to enable federated ecosystems, with common specifications and standards, harmonised rules and policies and a multi stakeholder governance to balance provider and consumer requirements.

In the context of GAIA-X, a federation is defined as a group of parties who share GAIA-X's core principles and build a self-governed digital ecosystem to make use of GAIA-X federated services.

With the scope on a combined infrastructure and data ecosystem, GAIA-X addresses key elements for a trusted offering of services, which include:

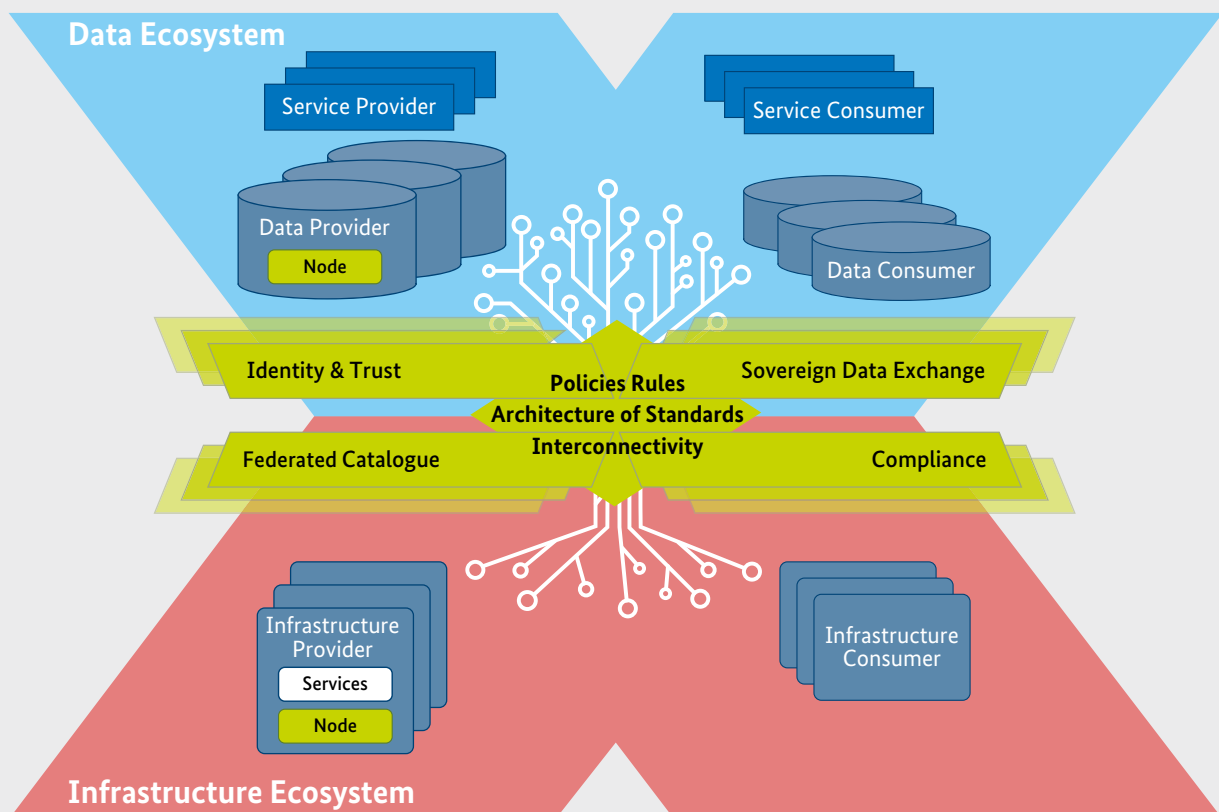
- Sovereign data exchange on a legal, architectural and technological level

- Compliance-supporting elements to adhere to regulation and policies
- Identity and trust services
- Catalogue for Services and Nodes according to GAIA-X requirements

Each federation can build their own GAIA-X federation by an assembly of services which are registered in GAIA-X federated catalogues.

Based on the current interconnection services, it is already possible, to separate networks within such a federation and to guarantee a data flow within specified parties. The federation governance can specify the level of security, the outreach of data location with respect to the applicable law and the onboarding of users who can join the federation.

Figure 7: GAIA-X federated data infrastructure



Node

A Node is one of the fundamental concepts of connecting real-world to the GAIA-X world: A Node is enabled by one or more GAIA-X Services to interact with other GAIA-X Services and Nodes. The generic term ‘Node’ emphasises the open and broad nature of GAIA-X.

Service Consumer

A GAIA-X Consumer is a registered natural or legal person who or which can access and/or consume Services.

of choice. They provide a transparent view of key aspects of services in terms of data sovereignty and features offered. At the same time, these mechanisms enable GAIA-X Providers to promote their services and nodes.

In order to fulfil these targets, GAIA-X supports the development of an open and federated system including the verification and certification of given aspects of the self-description. This will provide trust in published self-descriptions. Verification might include aspects like Accreditation, Certification or the local jurisdiction of GAIA-X participants. The list of verifications will increase with upcoming requirements for consumers and providers to be evaluated in the course of the project.

Federated Catalogue

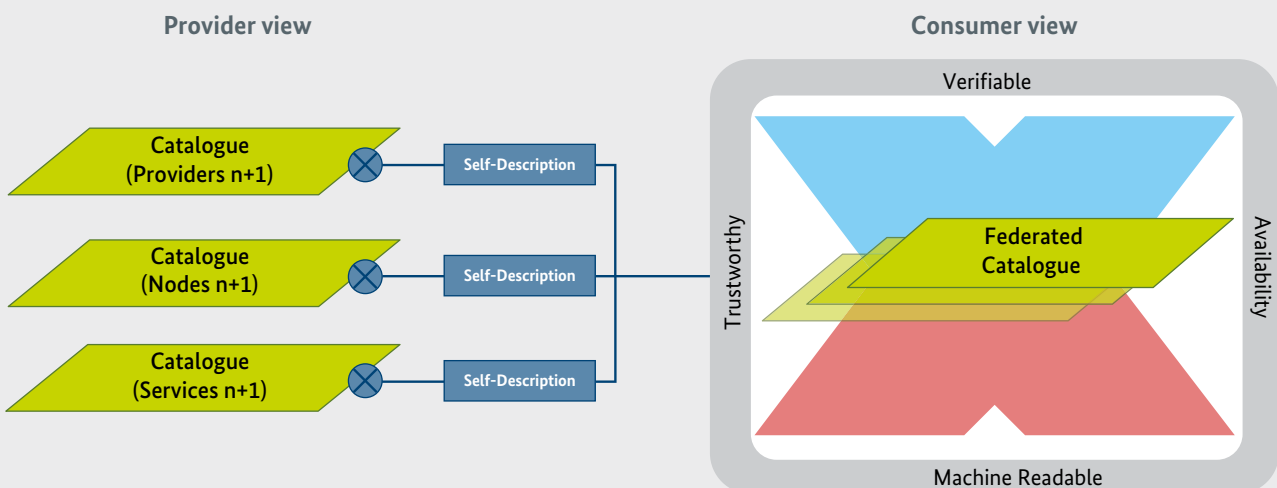
GAIA-X introduces self-descriptions (for example for services, nodes and providers) as well as federated catalogue to containing these descriptions. This enables consumers to obtain data and infrastructure services that fulfill their needs in terms of feature set, trust, data sovereignty and security.

GAIA-X Federated Catalogue give consumers and providers a user-friendly way of accessing services and nodes via APIs and Portals. In order to meet sector-specific demand, GAIA-X proposes ecosystem- and domain-specific profiles that include lists of required attributes.

GAIA-X Self-Description in combination with GAIA-X Federated Catalogue increase the consumer’s freedom

The set of relevant attributes will depend on the different data spaces (e.g. health or mobility) upon which these profiles will be created. Profiles are an optional

Figure 8: Federated Catalogue



and transparent mechanism that only clusters attributes and transparently shows the consumer the results for each of the given attributes.

GAIA-X Federated Catalogue are an open mechanism and the establishment of multiple catalogues is envisaged. Existing and future ecosystems will have the opportunity to include domain specific catalogues into the GAIA-X Federation of Ecosystems as long as they comply with the Transparency, Fairness, Security & Trust requirements of a GAIA-X Catalogue. GAIA-X will support a verification and certification process for these catalogues.

Certification and Accreditation of GAIA-X entities

The prerequisite for the certification and accreditation of GAIA-X services is a clear, structured model of **self-descriptions** including semantics to enable machine readability and to allow for dynamic evaluation.

A GAIA-X Self-Description is the structured, standardised specification of functional and non-functional properties of an element of the GAIA-X Ecosystem, for example a Node, a Provider or a Service. Self-descriptions serve three goals:

- **Matching/transparency:** service providers describe themselves and their services to GAIA-X customers so they can make an informed decision on the services they wish to use.
- **Instantiation:** self-descriptions contain all relevant information for instantiating services on demand, thus also supporting GAIA-X service provider operations.
- **Onboarding/certification:** a valid self-description of a provider and its offered services is a requirement for onboarding to GAIA-X. Moreover, relevant parts of self-descriptions may be covered by certification processes.

The approach stays independent from the underlying technology in order to quickly adapt to future trends,

as actual technology from its description. This helps to enable GAIA-X to reason about interoperability of services on a conceptual level.

As self-descriptions are machine readable, they are transformed into different representations such as the federated catalogue and standardised representations for instantiating services. The development of an appropriate data model, the relevant attributes, and necessary software is driven by the GAIA-X community on the basis of consensus mechanisms.

Onboarding and Certification

For participation in the ecosystem, adherence to the principles of GAIA-X is mandatory. These rules cover the particular areas of:

- **IT Security:** e.g. Information Security Policies, Personnel and Training, Asset Management, Identity and Access Management, Cryptography and Key Management, Physical Infrastructure Security, Operational Security, Communications Security...
- **Privacy:** Compliance of the entire processing operation with the requirements of the GDPR
- **Transparency:** e.g. Service levels, contractual basis
- **Interoperability:** The ability for one service to interact with other services by exchanging information and the portability of data according to the EU Free Flow of Data regulation

The compliance with these rules must be demonstrated by the provider of GAIA-X nodes and services and will be verified by an independent entity.

The goal is to design an approach which assures a **level of conformity** adequate to the GAIA-X principles, but allows also for organisations with limited resources (SME, Start-ups) to enter the GAIA-X Ecosystem. This implies that a clear and unambiguous indication of the level of assurance for each service/node has to be provided to allow for a customer to make an informed decision as to which service/node and provider match her individual preferences.

GAIA-X will **align its principles closely with existing initiatives** on the European level, therefore we follow a methodology according to the EU Cybersecurity Act with a staggered evaluation according to the risk classes of services or data.

An important basis for the evaluation process is the self-description to be provided by the provider (who applies for integrating services/nodes) in the GAIA-X environment. Other documentation to be provided by the applicant can include, among others: copies of standard service agreements, documentation on IT security management, existing certificates of the service provider and its subcontractors. Necessary data (provided by the applying provider) is **legally binding** and should be signed off by the management. Where possible, automated processes shall be used to answer the need for up-to-date certifications in the highly dynamic environment, lowering costs and effort for regular re-evaluations.

As already mentioned, the evaluation process follows a staggered approach:

For the **basic** level, the application request is examined by a qualified assurance auditor (mandated by GAIA-X) based on a guideline manual describing the examination process.

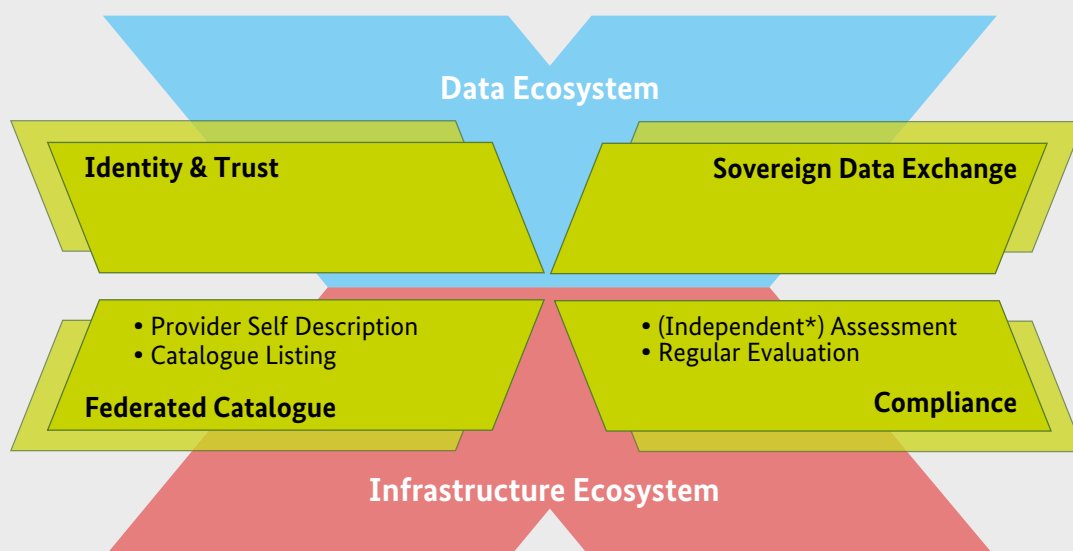
For **higher** levels (substantial and high) of service or node criticality a third-party based certification process will be in place.

This process is carried out by an independent accredited conformity assessment body (CAB).

To ensure a substantial level of assurance, the certification process has to be based on auditing standards that:

1. guarantee a sufficient level of formality and rigour,
2. are based on a thorough assessment and standard and repeatable processes,
3. offer an accurate reporting standard,
4. are based on clear and well-defined auditor competences requirements.

Figure 9: Standard process of Adherence



A goal of the GAIA-X certification process is to avoid duplicating audits and thereby reduce effort. Where an applying provider has obtained evidence derived from its adherence to an existing scheme (such as a certificate, attestation, standard or audit report), this evidence may be presented to the CAB in order to issue the certification of its certification object within the GAIA-X scheme. To this end GAIA-X will define and perpetually update the relevant set of certification/auditing schemes recognized to fulfil its requirements. As a basis the current work of ENISA in defining a European Framework for Cloud security certification will be taken into account.

For all levels, GAIA-X will establish a monitoring process overseen by an independent monitoring body and complaints management to ensure the long-term compliance of services. Due to the dynamic nature of infrastructure services GAIA-X will implement mechanisms for continuous monitoring of services and nodes. For the resilience of services cross over multiple providers and a basic assurance of Service Level Agreements, continuous monitoring targets the core requirements of transparency, service functionality and control of data.

Data Sovereignty Services

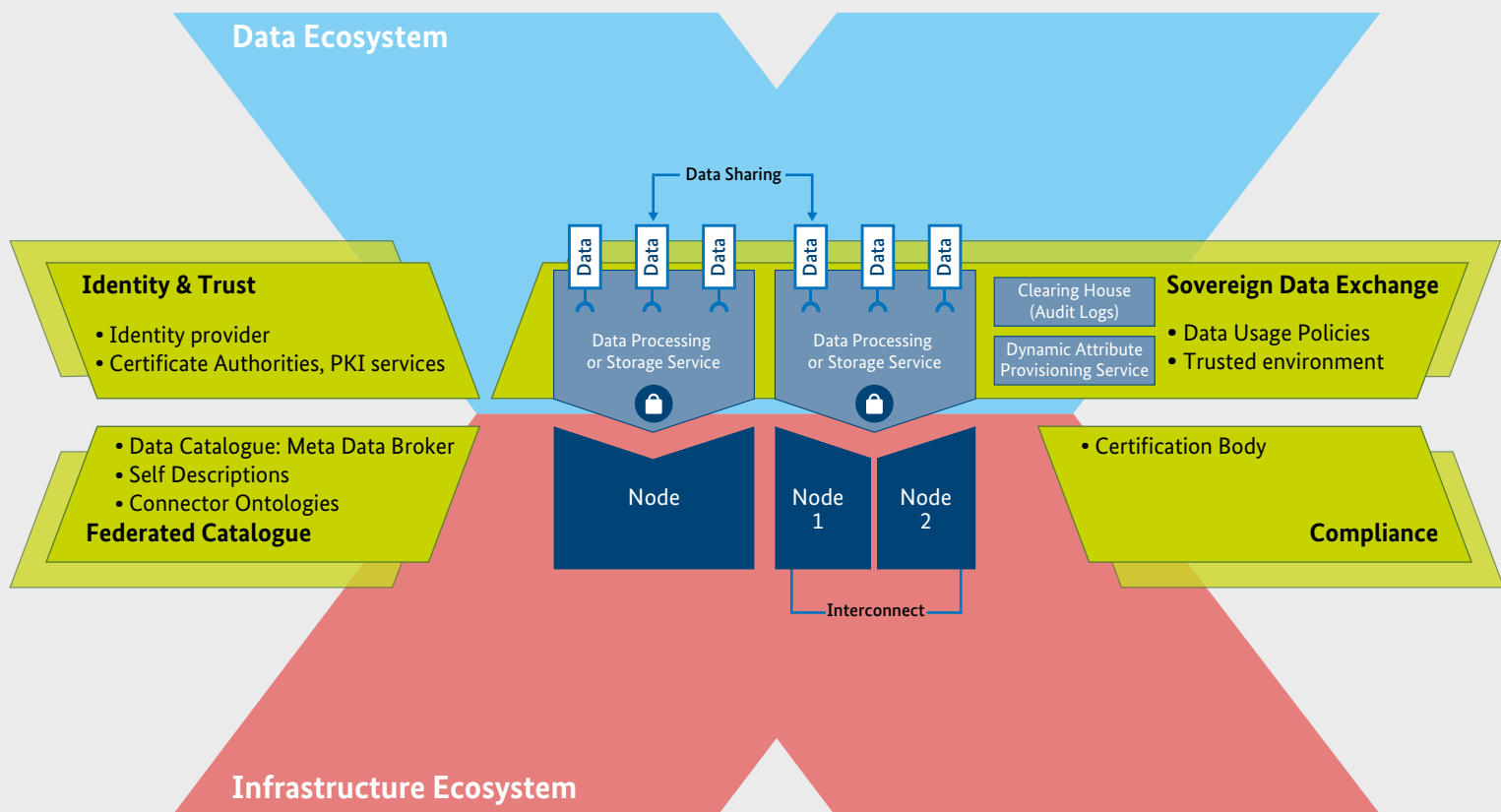
The need for sovereignty of infrastructure operation as well as identity access is a major driver for GAIA-X. Therefore, one of its core functions is to give the consumer appropriate measures for the exclusive decision on the usage of cloud resources for service consumption, data processing and other activities. Important concepts for the **sovereignty of consumers** are interoperability (on certain aspects, e.g. Digital Identities, Metadata, Descriptions), trust among different parties and accepted, enforceable governance. This includes technical measures to protect data against access by the node/service provider. Data sovereignty can be described as the ability of a natural or legal person to decide exclusively on how the data she has provided is to be used.

To do so **interoperability on Metadata Level** is a prerequisite, as well as a comprehensive Trust Framework as a foundation for the capability to make self-determined decisions about how the data is to be used and processed. In a common cloud scenario, typically the provider of the data processing (as a general term) environment is not the user or consumer of the data. Therefore, the Trust Framework must include this aspect in the federated catalogue from a planning perspective but must also include supporting concepts at runtime. This includes an agreed and common set of security mechanisms that are scalable with regards to the required level of trustworthiness. The requirements for the level of trustworthiness can be derived from regulations, company policies or other sources and must be aligned with the certification efforts of GAIA-X.

The enforcement of data usage policy is of key importance. The realisation of data sovereignty is enabled by the ability to state Usage Policies for the Data that can be enforced even after the data has left the security domain or data center of the data provider. Technical enforcement of Usage Policies can be implemented by suitable frameworks and include the ability of **decentral and auditable logging**. This must be accompanied by organisational and legal measures, e.g. a **comprehensive governance framework** as well as a well-defined security architecture based on hardware trust and comprehensive trust models for gateways, infrastructure services and software artefacts. GAIA-X provides such a comprehensive framework as an open Reference Architecture Model based on existing standards. The concepts for data sovereignty specified in this Reference Architecture Model will be aligned with the GAIA-X Architecture to ensure data sovereignty in the context of GAIA-X.

The realisation of data sovereignty requires the availability of so-called essential Services for Data Sovereignty. This is basically the functionality of a **federated Identity Provider (IdP)** that ensures trusted Identities with verified and authenticated attributes based on Certification and (continuous) monitoring. On top of the essential service the base services enable the core functionalities for data exchange and data sharing,

Figure 10: Data Sovereignty Services overview



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e.g. auditable logging, clearing and settling, as well as (meta-) data brokerage. The functionality of the essential services and partly the base services are required for the enforcement of usage policies on top of data as they enable the decision making process. The enforcement of the usage policies is the duty of the service, node and provider.

A GAIA-X consumer would ask for a comprehensive view on GAIA-X Providers, Nodes and Services (may optionally include data usage policies and capabilities) in a federated catalogue including available datasets and data sources as well as security guarantees. The integration of GAIA-X self-descriptions and metadata of datasets and data sources in a federated catalogue enables sovereign data exchange and data sharing in GAIA-X.

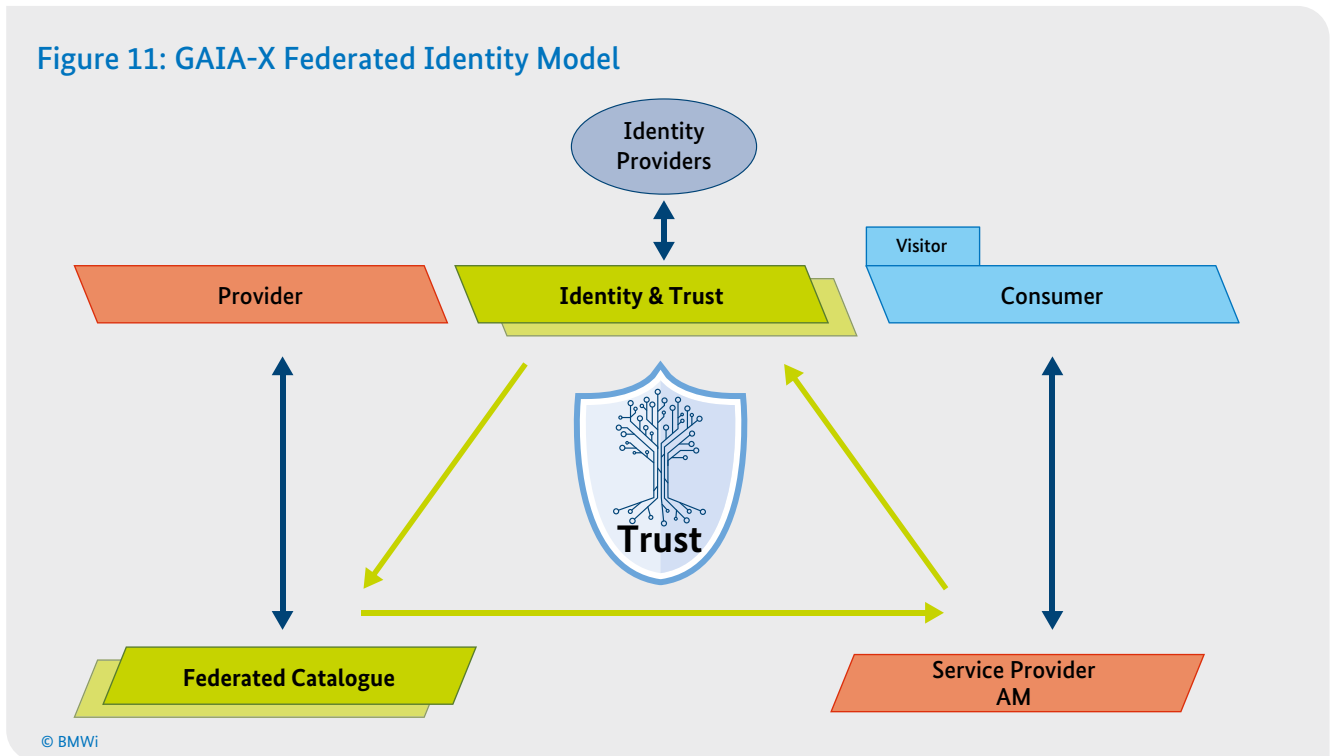
Federated Identity & Access Management

GAIA-X Identity and Access Management (IAM) validates identities and manages the right stakeholders to access the right resources for a given context produced in the federated ecosystem.

The introduction of GAIA-X focuses on provisioning a governance trust framework, without modifying the actual identity approach or touching the existing authorisation policies.

GAIA-X will provide consistent identification of entities within the system. Authorisation decisions are still to be taken according to the provider's local policy. To ensure a secure interoperability among mesh

Figure 11: GAIA-X Federated Identity Model



participants, an overarching trust infrastructure with an agreed-upon semantic layer of authentication and authorisation decisions will be provided.

GAIA-X Federated Identity Model provides a proper level of trust to information they derive from the Identity Provider (IdP) system. GAIA-X Federation and service providers will offer a high degree of security regarding the integrity, confidentiality, traceability and auditability of GAIA-X identities. GAIA-X enables common ways to authenticate and authorise technologies but does not enforce specific implementation.

The following GAIA-X participants are displayed in the federated Identity model.

- **Provider:** A Provider registers his organisation to register his Nodes or Services in its ecosystem, which will be accessible for the public.
- **Consumer:** A Consumer is a registered GAIA-X participant who can search/browse the GAIA-X Catalogue and order Services. The identity of the Consumer is verified by an IdP.

- **Identity provider (IdP):** The IdP ensures the trustworthiness of the participants in the GAIA-X ecosystems.
- **Visitor:** A Visitor is a non-registered participant who can browse/search the Catalogue for possible Services which he is interested in.

Currently, GAIA-X IAM concentrates on the core mechanisms of identity and access management, while authentication of entities (Provider/Nodes/Service/Consumer/Devices) is key to enabling a trusted GAIA-X, providing the foundation of the GAIA-X data sovereignty. This includes the integration of trust frameworks to support decentralised data infrastructures.

The identity and access management will be based on industry best practices and international open standards. It focusses on ensuring the interoperability of identification, authentication and authorisation, based on conceptual design and architecture by adopting accepted architectures, protocols, international open standards, industry best practices and frameworks.

A proper lifecycle management is required and must cover identity onboarding, e.g. registration and binding of initial credentials (establishing of identity accounts for individuals, entities and IOT devices). The onboarding process is based on credentials (entity, node and services), a trust infrastructure and authentication including the verification of assurances given by GAIA-X Certification and Monitoring, and any eventual off-boarding or suspension activities.

In the business alignment, it will be necessary to support ongoing due diligence referring to activities of actors and consumers regarding identity and access control. Also, in this area the topic of policy management (and policy enforcement) will play a key role. A challenge to be solved in this area is a policy matching between domain specific requirements, in order to enable customers to choose a geography/jurisdiction for data storage and processing offers.

Summary & Outlook

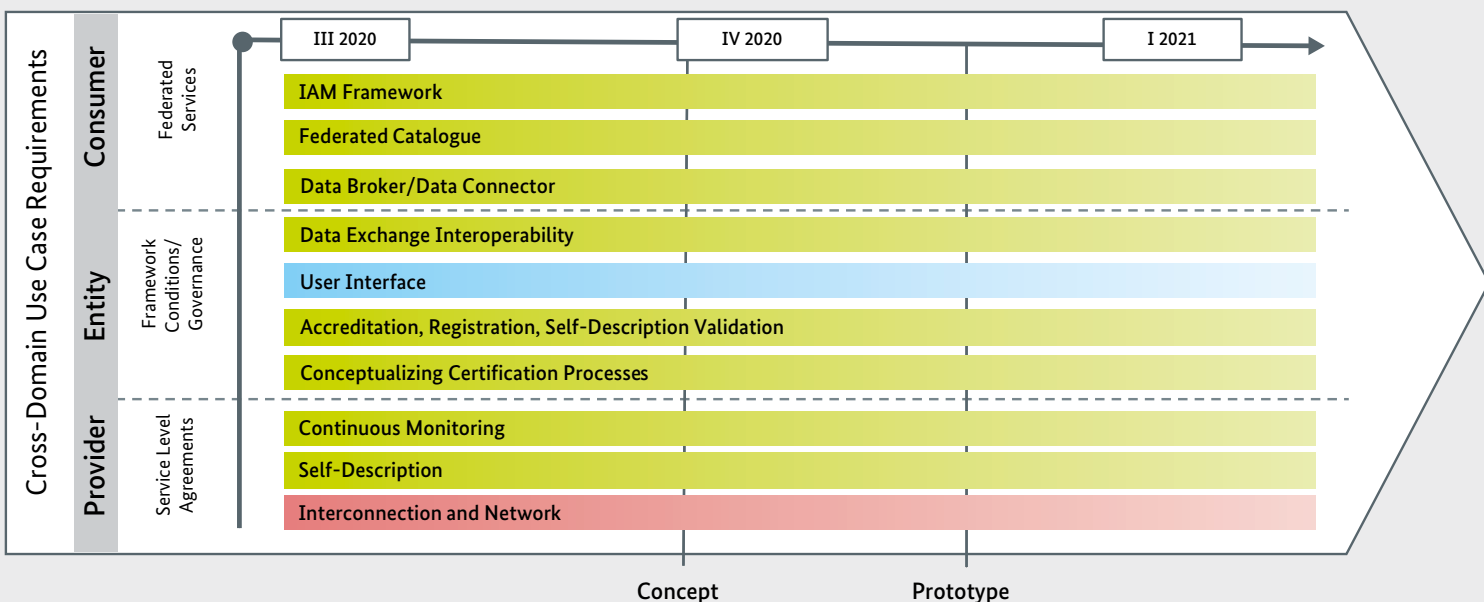
GAIA-X combines the technological and industrial strengths of EU industry, academia and the public sector to develop an ecosystem of data and infrastructure providers and a regulatory framework based on fundamental European values and standards. The initiative supports the target of the EU to become a global leader in innovation in the data economy and its data-driven applications as set out in the European data strategy.

GAIA-X investigates the need of an overall far-reaching target architecture and complementary approaches for the vision of the **federated data infrastructure**, beyond existing cyber security and data protection approaches. GAIA-X also contributes to **sustainable data sovereignty** and strengthens Europe's competitiveness in the global digital market. In accordance with the current EU data strategy, the project initiative promotes the development of a complete value chain of data generation, processing, access and re-use, thus avoiding the necessity for multiplication of fragmented cloud federation and data-sharing initiatives.

The underpinning of the sovereign data value chain is a sovereign infrastructure stack. The data processing services and providers can express functional and non-functional requirements to the node providers. GAIA-X helps to fulfill these requirements by creating a standard description of these which, in turn, creates transparency. GAIA-X further supports the infrastructure service providers with a compliant modular open source software stack that can be used (as a whole or cherry-picked) to create federable, interoperable, and secure infrastructure services.

Added value will be created for European citizens who will benefit from improved and sustainable public services in areas such as health care. European businesses can rely on a trustworthy, flexible and user-friendly digital environment for the development of new products and services across EU key sectors e.g. machinery, cybersecurity, healthcare, energy or industry 4.0. Finally, the public sector gains improved access to suitable tools ensuring citizen security, enabling law enforcement authorities and increasing efficiency and effectiveness of public administration. A vibrant ecosystem of interoperable

Figure 10: Roadmap



node providers lowers the barrier to access modern self-service automated IT infrastructure, thus removing a significant obstacle to enhanced software engineering innovation.

GAIA-X provides *the essential features of security, sustainability, interoperability and scalability* for future data infrastructure in Europe. Therefore it includes the following *Federation Services* as a foundation for further development:

- Specify the structure of a Federated Catalogue in order to make all information about participating providers, accessible nodes and services visible (machine readable).
- Define the certification and accreditation of GAIA-X entities in accordance with European standards and regulations.
- Establish guidelines and references for Sovereign data exchange
- Provide Identity and Trust services to validate identities and manage the access of stakeholders to resources in a given context

On that basis, start-ups, medium sized enterprises, corporations, and research institutes receive a framework of policies, standards and services to enable the development of an *innovation ecosystem* that brings the *benefits of data-driven value creation to the whole of the European society and economy*.

The project GAIA-X strives onto a permanent basis, in the form of an organisation with legal capacity whose objective will be to advance and implement an European data infrastructure. In particular, this organisation will drive forward the elaboration of the reference architecture that the federated data infrastructure uses. It will also be responsible for determining and specifying the data infrastructure's technical requirements and its body of rules.

The initiative will facilitate this development with its competences and expertise and foster research and development (R&D) where needed. In order to ensure stable practices, align processes with strategic objectives and encourage continuous improvement of business processes the GAIA-X entity will establish an *overall governance framework* with rules and guiding principles including

- Certification and accreditation criteria
- Onboarding process of new participants
- Monitoring complaints management and dispute resolution
- Adaptation of the GAIA-X processes to regulatory requirements
- Structure and procedures of governing bodies
- Alignment with intra and inter domain organisations

The **integration of European and international partners** is a major component of the initiative. Therefore the creation of a community of governmental, private and academic stakeholders is further enhanced. This process is driven by the integration of cloud users and providers from all over Europe and is supported by joint communication activities and events.

In order to address these intentions and transfer the conceptual foundations into practice, GAIA-X members have defined a roadmap for execution. The roadmap includes and contributes to the Federated Services of GAIA-X and an overall governance framework which is essential for the future setup of the initiative. Furthermore the roadmap reflects the Service Level Agreements with which GAIA-X providers have to comply. The roadmap topics are organised in work packages in order to achieve a first GAIA-X prototype by early 2021.

